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Cessna

MODEL 309A-309C REPORT NO. 9
319A

APPLICATION OF CIRCULATION CONTROL TO
AN AIRPLANE OF MILITARY LIAISON TYPE
NONR CONTRACTS 234(00) AND 856(00)

Cessna Aircraft Company
Wichita, Kansas

CESSNA AIRCRAFT COMPANY

RESEARCH DEPARTMENT AIRCRAFT DIVISION

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Report No. 9

Report Title Application Of Circulation Control To An Airplane of Military Liaison Type

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Cessna
Aircraft Company
Wichita, Kansas

Engineering Report

July 13 through August 11, 1953

MODEL 309A-309C 319A : REPORT NO. 9

APPLICATION OF CIRCULATION CONTROL TO AN AIRPLANE OF MILITARY LIAISON TYPE

NONR CONTRACTS 234(00) AND 856(00)

REPORT DATE: August 31, 1953

PREPARED BY: Earl G. Blosser

WITNESSED BY: Jack W. Fisher

APPROVED BY: Alex N. Petroff

CESSNA MODEL 309A and 309C - NONR CONTRACT 234(00)

Analysis

First drafts of reports on Model 309A (Electrical System) presenting take-off and landing data and analysis are complete. Only final review remains before release.

Model 309C - Flight Tests and Analysis

A total of three flights have been made including shakedown, airspeed calibration, and a series of stalls. Ground runs for measurements of mass and quantity flow were also conducted.

The H_2O_2 boundary layer control jet pump was operated on the last two flights. Indicated stalling speeds did not appear to be substantially different from those observed with the axial fan installation. These stall speeds are currently being reduced to values of $C_{L_{max}}$ for a more definite comparison.

Flight Tests

With the completion of the installation of the H_2O_2 unit in the 309C the airplane was ground tested on July 17, 1953. The unit functioned properly in all respects. Total system operation was twelve minutes. During these ground tests quantity flow readings were photographed. Unfortunately due to malfunction of the camera the results were not readable. It is planned to re-run these quantity flow tests during the week of July 27, 1953.

Initial flight tests were conducted during the week of July 20. In all three flights were conducted. The first flight was a shake-down flight to determine if any unusual flight characteristics existed. The second flight was for airspeed system calibration. During the third flight stall speeds were measured at various altitudes, with and without BLC, using different control deflections.

Aerodynamic performance, as determined from flight data, was essentially the same as shown by earlier versions (gas turbine and burner with a jet pump, and direct current electric, axial fans).

A severe binding of the aileron occured with the BLC system in operation due to thermal expansion of top skin caused by hot air ejected through the blowing slot. This is being corrected by reinforcement of the aileron spars and increase of clearance between the aileron and the wing. Shop rework is nearly complete, and tests will be continued during the next week.

Future flights will include additional stalls to evaluate the aerodynamic performance and to establish take-off and landing approach speeds. Also, quantity and mass flow measurements will be made with the airplane on the ground. This repeat of previous testing became necessary with the increase of of blowing slot width.

Results and Discussion of Initial Tests - Flow Measurements

With a slot width of 0.75% chord, ground test measurements indicated a mass flow of 8.5 lbs/sec. and a flow quantity of 132 ft.^{3}/sec. These values are given for both wing panels, and include the mass of the propellant (decomposed H_2O_2).

Velocities were measured with pitot static tubes at 12 spanwise locations, and the resultant values were multiplied by local slot width. These were then plotted as shown (Figure 1) and a graphical integration performed.

The plot of Figure 1 also gives an indication of the spanwise distribution which was similar to the pattern obtained on the 309A (D.C. electrical system with axial fans - Reference 1).

Reaction Motors personnel have measured mass flows of 4.88 lbs/sec. in one wing panel, which would indicate a total flow of 9.76 lbs/sec. This would be approximately 15% greater than measured on the airplane, but this flow occured

through a larger slot. For this reason the blowing slot width is being enlarged from 0.75% to 0.90% chord.

Flight Results

The flight program was limited due to the severe aileron binding; however, an airspeed calibration was accomplished, and a number of pilot-observed stall speeds were collected. These speeds have been reduced to values of $C_{L_{max}}$ and are compared by Table 1 to similar stall points of the airplanes with other boundary layer control (BLC) systems.

Table I

Configuration				$C_{L_{max}}$		
δ_F (deg.)	δ_A (deg.)	BLC	Engine Power	309	309A	309C
45	0	Off	Off	1.86	1.86	1.64
		On	Off	2.13	----	2.06
		Off	F.T.	2.53	2.34	2.16
45	0	On	F.T.	2.91	*2.97	2.78
45	30	Off	Off	2.06	1.85	1.72
		On	Off	2.32	----	2.25
		Off	F.T.	2.72	*2.25	2.55
45	30	On	F.T.	3.45	*3.04	3.19

* These values represent engine power required for level flight. Full throttle conditions are designated by F.T.

It should be noted that the values given for the Model 309 (gas turbine bleed and burn with a jet pump) were computed from photographic recordings while those values for the 309A and 309C are based upon pilot-observed data. Also, in this region of low stalling speeds, a difference of 2 mph can produce a change in $C_{L_{max}}$ as great as 0.4. So a reasonable amount of point scatter was expected; however, in all cases values for the 309C were less than those for the 309, with and without BLC. Essentially, the external configurations of these two versions of the airplane were identical except that small

differences of the slot width between aileron and wing existed. This, in addition to discrepancies between photographed and pilot-observed data, accounts for the lower values of $C_{L_{max}}$ measured with the 309C.

In general, it is concluded that the aerodynamic performance of the airplane with a H_2O_2 jet pump BLC system and with a blowing slot width of of 0.75% chord was not substantially different from earlier versions of the airplane. The stalling speeds (and $C_{L_{max}}$) may be improved by enlarging both the blowing slot and the slot between aileron and wing. This remains to be shown by the projected testing program.

Performance of the Hydrogen Peroxide System

The H_2O_2 unit has performed satisfactorily to date. Initial tests were conducted on the ground both with the airplane engine stopped and with RPM settings from idle conditions to full throttle. Vibration caused no malfunctions at any time either on the ground or in flight.

Handling H_2O_2 in refueling operations presented no difficulties with the special service truck made available by Reaction Motors. The only unusual factor was that an ample supply of water was required to dilute any H_2O_2 which might come in contact with organic matter.

Reaction Motors personnel currently remaining at Cessna include only Mr. G. Yanvary, During this period Mr. Brukardt and Mr. Singleton returned to Dover, New Jersey. Mr. Gordon Luessen of Cessna is assisting with refueling and maintanence of the hydrogen peroxide unit.

Shop

The blowing slot adapter, Part No. 12309-22, was removed and Part No. 12309-45-3 was used to replace it. By changing these adapters the physical width of the blowing slot was changed from .75% to .90% chord.

The ailerons were re-worked by the addition of two .051 bulb angles to both the upper and lower aileron spar. Addition of this increased stiffness to the aileron was needed to reduce aileron bending when jet pumps were in operation.

CESSNA MODEL 319A - NONR CONTRACT 856(00)

Analysis - Stability

As has been previously reported, the values of downwash angle, wake location, and loss of dynamic pressure in the wake (necessary for calculation of longitudinal stability and control) have been based upon the commonly accepted NACA charts and methods. For the cases with BLC producing lift coefficients from 3.0 to 4.0, and higher, the values given by these methods may vary considerably from the actual case. No experimental data exists from which verification can be established. The University of Wichita Aerodynamic Report No. 097, received by Cessna during this period, presents limited tuft grid studies of the flow pattern aft of the 0.6 scale 319 wind tunnel model. These grid patterns show the existence of a large wake region for the configuration with flaps deflected-BLC off. This region of heavy turbulence completely disappeared when BLC was applied indicating that wake losses (at normal tail locations) would be considerably less than computed. In addition, the observed angles of downwash aft of this wing appeared larger than those calculated. While these observations do not represent quantitative data, they are an indication that the problem of elevator deflection required to land may not be as serious as shown by preliminary calculation. Nevertheless, there still exists great need for a program which would yield useful design information pertaining to stability and control of BLC airplanes.

Investigation of the elevator required to 3-point landing has been completed. Conclusions were as follows:

1. Design data concerning downwash angle and wake losses aft of a BLC wing is very inadequate. Computations of elevator deflection required to land must be considered as preliminary until verification is obtained from either flight data or additional wind tunnel tests.

2. Installation of the Cessna Model 180 variable incidence horizontal tail is required for satisfactory performance of this airplane with BLC operating.

3. Most forward c.g. location will be restricted to 25% of mean aerodynamic chord.

4. A 25% increase of elevator area will also be required.

First flights of the airplane will be performed with the Model 180 tail installed, but without the additional elevator area. The requirement for increased area, as shown by calculation, will then be definitely established by flight data.

Ducting

Aerodynamic design of the blowing duct has been initiated with the consultant advice of Mr. Kenneth Razak. The duct will be designed in such a manner that the pressure difference between duct centerline and blowing slot will be constant in the spanwise direction, except for a small region directly aft of the fan hub. There, a series of small turning vanes will be required for optimum flow distribution.

Design

Drawing 12319-24, Suction Duct Installation, has been finished and prints released to the shop. It covers the manufacture and installation of the suction duct.

Drawing 12319-23, Empennage Installation is now completed. The shop has been furnished copies of the prints.

A drawing has been started showing the installation of the hydraulic system in the airplane.

Drawing 12319-26, Pressure Pick-Up Installation, has been started. It will show the installation of the required pressure pick-ups for the 319A quantity flow measurements.

Shop

The suction flaps and the blowing flaps have been completed.

The installation of the 180 empennage on the 319A is now complete except for final inspection and riveting of the splice plate. (See photo)

A mould for the suction duct is being made. The fiber glass duct will be formed when this mould is completed.

Templates and form blocks have been made for the suction duct ribs.

Pulley brackets to be used for the aileron installation are also being manufactured.

Trip by A. Petroff to Los Angeles, July 15-17

The purpose of the trip was to establish engineering contacts with several firms manufacturing solid and liquid propellant gas generators and turbines suitable for application to BLC. The following firms were visited:

AiResearch Manufacturing Co. - Los Angeles, Calif. - July 15, 1953 - Pumping requirements were presented to Mr. A.T. Agern, Sales Engineer and to Messrs. Chapman and Drexel of the turbine division. They agreed to look into the matter and see if there is a turbine which would fit Cessna specifications with minor adaptation.

Turbo Products Inc., Pacoima, Calif. - July 16, 1953 - Mr. J. Golden, Director of Engineering, Mr. R.A. Holzl, Chief Development Engineer and Mr. P.C. Ricks, Chief Design Engineer expressed interest in application of their product to BLC. Turbo-Products, Inc. developed small ethylene oxide gas generator and turbine unit which could be adapted to our needs. A proposal will be made and presented to Cessna in two weeks.

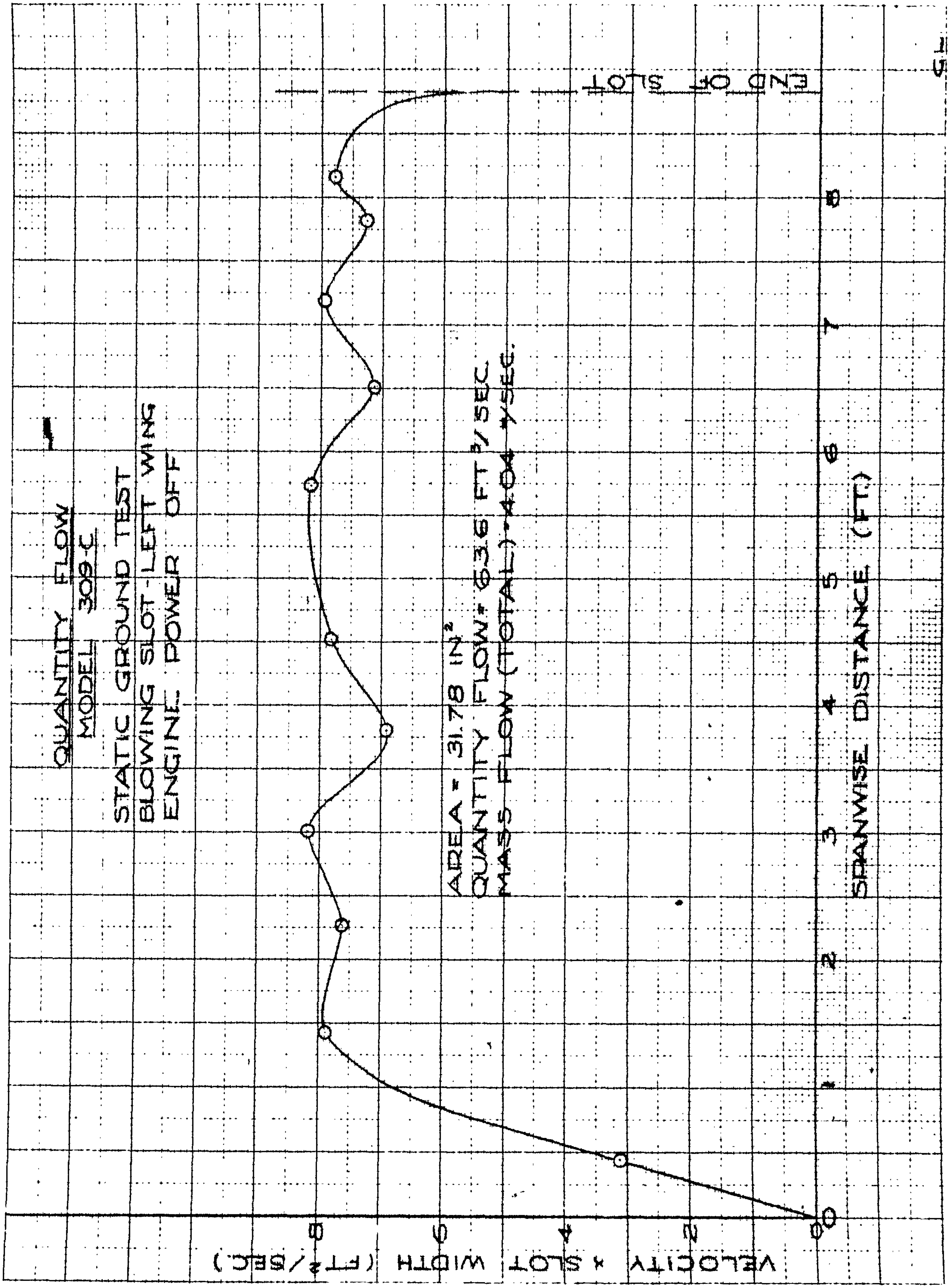
Aerojet-General Corp. - Azusa, Calif. - July 17, 1953 - Mr. W.L. Gore, Director of Field Service, was also interested in application of their product to BLC. Aerojet developed a small solid propellant gas generator and turbine

unit for missile work. It is very light, compact and has the right amount of power for our needs. Mr. Gore agreed to submit a proposal for adaptation of the unit to Cessna BLC requirements.

The above mentioned systems are being evaluated from the standpoint of:

1. Thermodynamic and mechanical efficiency.
2. Weight for a given period of action.
3. Compactness.
4. Adaptability to the airplane.
5. Logistics of the fuel.
6. Price.
7. Delivery dates.

The results will be presented to the Office of Naval Research for consideration as a possible avenue for future research of pumping systems, applicable to BLC requirements of liaison type airplanes.


QUANTITY FLOW
MODEL 309-C
STATIC GROUND TEST
BLOWING SLOT - LEFT WING
ENGINE POWER OFF
AREA = 31.78 IN²
QUANTITY FLOW = 63.6 FT³/SEC
MASS FLOW (TOTAL) = 4.04 #/SEC.
END OF SLOT
SPANWISE DISTANCE (FT)
VELOCITY × SLOT WIDTH (FT²/SEC.)
0
2
4
6
8
1
2
3
4
5
6
7
8

TITLE

PREPARED BY DATE

CHECKED BY DATE

FORM 4-4

CESSNA AIRCRAFT CO.

WICHITA KANSAS

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